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Co-evolution of soil and water conservation policy and human–environment linkages in the Yellow River Basin since 1949

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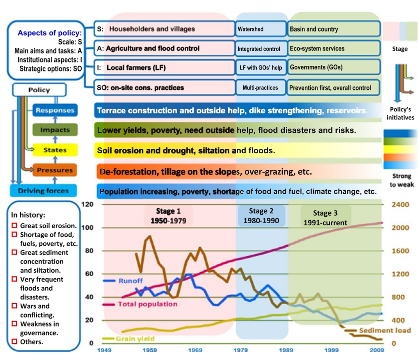
HIGHLIGHTS

- Outlining complex problems and policy responses in China's soil erosion hotspot
- Detecting policy co-evolution with human–environment linkages using DPSIR
- Policy addressing real conditions mainly affected the environment initially.
- Policy improved the rural economic and ecosystem when solving river's problems.
- Providing a historical perspective on resource management with an actual story

GRAPHICAL ABSTRACT



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ABSTRACT

Policy plays a very important role in natural resource management as it lays out a government framework for guiding long-term decisions, and evolves in light of the interactions between human and environment. This paper focuses on soil and water conservation (SWC) policy in the Yellow River Basin (YRB), China. The problems, rural poverty, severe soil erosion, great sediment loads and high flood risks, are analyzed over the period of 1949–present using the Driving force–Pressure–State–Impact–Response (DPSIR) framework as a way to organize analysis of the evolution of SWC policy. Three stages are identified in which SWC policy interacts differently with institutional, financial and technology support. In Stage 1 (1949–1979), SWC policy focused on rural development in eroded areas and on reducing sediment loads. Local farmers were mainly responsible for SWC. The aim of Stage 2 (1980–1990) was the overall development of rural industry and SWC. A more integrated management perspective was implemented taking a small watershed as a geographic interactional unit. This approach greatly improved the efficiency of SWC activities. In Stage 3 (1991 till now), SWC has been treated as the main measure for natural resource conservation, environmental protection, disaster mitigation and agriculture development. Prevention of new degradation became a priority. The government began to be responsible for SWC, using administrative, legal and financial approaches and various technologies that made large-scale SWC engineering possible. Over the historical period considered, with the implementation of the various SWC policies, the rural economic and ecological system improved continuously while the sediment load and flood risk decreased

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dramatically. The findings assist in providing a historical perspective that could inform more rational, scientific and effective natural resource management going forward.

1. Introduction

Soil erosion has important impacts, both on-site and off-site (Vignola et al., 2010; Wossink and Swinton, 2007), including the reduction of soil depth, impairing the land's productivity, and the transport of sediments, leading to deposition that degrades streams, lakes, and estuaries (Uri, 2001). In China's Loess Plateau, extensive soil erosion and water loss have historically induced soil degradation and soil water shortages, lowering crop yields, and exacerbating rural poverty, arable land and biodiversity loss on-site (Meng, 1997). It has also induced sedimentation in the Yellow River (which has the greatest sediment load in the world), reducing reservoir capacity, causing the riverbed to rise, increasing the risk of flood disasters, increasing the maintenance costs of the river banks, and requiring more water to flush the sediment to the sea (Zhao, 1996; Wu et al., 2005; Mu et al., 2004).

Management of soil erosion in the China's Loess Plateau has relied largely on the development and implementation of policies, which, over time have greatly decreased the sediment load of the Yellow River. Indeed, the mean annual suspended sediment load at Huayuankou declined from 1.36 billion tons in 1956–1970 to 0.23 billion tons in 1996–2010 (15 years) (Meng, 1997; Tang, 2004). This paper unpacks how policy approaches have changed over time to achieve this improvement.

Science and policy are both relevant to land management (Freyfogle and Newton, 2002; Stringer and Dougill, 2013). Although policy plays an increasingly important role in environment and resource management, and is considered fundamental to biodiversity conservation and watershed management (Jansen et al., 2006; Miller et al., 2009), the success of policy initiatives is contingent on effective stakeholder engagement or public involvement (Cocklin et al., 2007; Stern and Mortimer, 2009). Policies can include land rent change, voluntary or 'soft' policy based mainly on education, legal regulation, and national and local laws and actions (Bennett and Vitale, 2001; Kelly, 2006; Hanna et al., 2007; Gotmark et al., 2009; Stern and Mortimer, 2009; Angelsen, 2010). Policy in this article is defined as "a set of decisions which are oriented towards a long-term purpose or to a particular problem. Such decisions by governments are often embodied in legislation and usually apply to a country as a whole rather than to one part of it" (Sandford, 1985, p. 4).

Research in the Yellow River Basin (YRB) to date has focused mostly on SWC practices on the catchment slopes and how to dam the main stream to reduce sedimentation on the riverbed of the lower reach (YRCC ECR, 1991; Meng, 1997; Tang, 2004). Research on the role of SWC policies is sorely lacking. While some analyses on SWC policy changes exist at a regional scale in China (Ding, 1989; Guo, 1995), they just describe the policy and pay very little attention to the impacts. In focusing on the co-evolution of SWC policy and human–environment linkages in the YRB in this paper, we argue that it allows an opportunity for policy learning and to see what kinds of interventions have the desired environmental impacts. These lessons can then be applied in future policy developing, helping to guide it to better address some of the key drivers, pressures and impacts of soil erosion.

The goal of this paper is to analyze the SWC policy changes in the YRB since the foundation of the People's Republic of China in 1949. This period fits well with document availability. The next section sets out our study area and methods used. After that, we use the Driving force–Pressure–State–Impact–Response (DPSIR) framework as an organizational tool in order to explore on the whole picture of the SWC challenge and the ways in which the policies affected the drivers, pressures and states of the environment.

2. Research design and methodology

2.1. Study area

The Yellow River is the second largest river in China (Fig. 1) with a drainage area of 752,000 km^2 and a length of 5464 km. It originates from the Qinghai–Tibet Plateau, flows through the Loess Plateau and the North China Plain (elevation below 100 m), and empties into the Bohai Sea. The basin covers 9 provinces or autonomous regions, was home to 110 million people in 2000, and accounted for around 9% of China's total population (Giordano et al., 2004). The YRB covers a wide range of vegetation types and climatic zones because of this large area and elevation gradient. Mean annual precipitation in the basin is approximately 479 mm, but the regional and seasonal distribution is very uneven due to the great influence of the monsoon season. About 60% of precipitation falls in the rainy season from June to September (Zhao, 1996). The loess in the middle reaches of YRB is very prone to erosion, causing the sediment load and concentration of the Yellow River to be very large (Zhao, 1996; Walling and Webb, 1996). The mean annual sediment load was 1.6 billion tons and the average sediment concentration 37.8 kg m^{-3} based on measured data at Sanmenxia Hydrologic Station from 1919 to 1986 (Zhao, 1996). Over time, sediment deposition in the downstream river channel has caused the riverbed to be up to 10 m higher than the surrounding land surface in some places, a condition known as a "suspended river" or "perched river" (Wu et al., 2005). Over thousands of years of Chinese history, frequent catastrophic floods in the YRB have resulted in tremendous losses of life and property (Hu et al., 1998).

2.2. Method and data

2.2.1. Framework of analysis

DPSIR framework (OECD, 1993; Gabrielsen and Bosch, 2003; Gobin et al., 2004; Borja et al., 2006; Martins et al., 2012) provides the conceptual framework for better understanding the complex relationship between soil erosion and policy responses (see Fig. 2 for a brief overview). In the context of its application in the present study, it allows us to explore the effects of responses on drivers, pressures, states and impacts. Driving forces for SWC in the YRB include both natural and socio-economic factors that disrupt the environment's ability to provide provisioning ecosystem services, including e.g. food, fuel and forage (Fig. 2). Shortages of these services drive environmental pressures such as cultivation on slopes, deforestation and over-grazing. This leads to soil erosion that has both on- and off-site effects. Society nevertheless responds with various policy measures such as regulation and information provision, and in some cases, negative strategies that could worsen the pressures. Feedbacks between responses mean that the ways in which the problem of soil erosion is handled could affect driving forces (R1), pressures (R2) and/or states (R3). Responses to states (R3) might thereby have limited effect as they merely addresses symptoms of land degradation, whereas positive responses to the driving forces (R1) could improve the regional economic and food condition over the long-run as a solution to soil erosion control. These kinds of relationships form the focus of our analysis.